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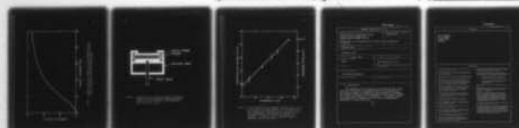
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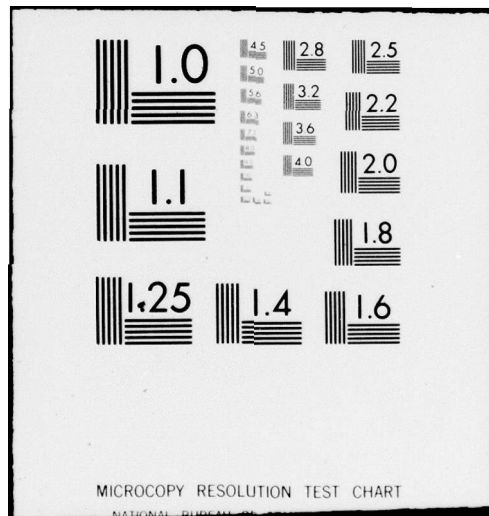
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DREO TECHNICAL NOTE NO. 79-1  
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**AN APPARATUS FOR THE MEASUREMENT  
WATER-VAPOUR PERMEABILITY OF TEXT**

by

**B. Farnworth**



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9) TECHNICAL NOTE NO. 79-1

6) AN APPARATUS FOR THE MEASUREMENT OF THE  
WATER-VAPOUR PERMEABILITY OF TEXTILES.

by

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### ABSTRACT

An apparatus has been constructed to measure the water-vapour resistance of textiles, in particular those such as battings and piles that are highly air permeable and have low vapour resistances. The technique has been tested by measuring the water vapour resistance of air gaps in the range 1 to 8 mm thickness. No systematic errors were observed with a random error in the resistance measurement equivalent to 0.5 mm of still air.

### RÉSUMÉ

On a mis au point un appareil pour mesurer la résistance des textiles à la vapeur d'eau, et particulièrement de ceux, comme les tissus peluchés et d'autres à formation en nappes, qui sont très perméables à l'air et offrent une faible résistance à la vapeur. La méthode a été éprouvée par la mesure de la résistance à la vapeur d'eau, d'espaces d'air, d'une épaisseur de 1 à 8 mm. On n'a pas relevé d'erreurs systématiques, et ce pour une erreur aléatoire dans la mesure de la résistance, équivalente à 0.5 mm d'air immobile.

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## INTRODUCTION

Since the accumulation of water in clothing as a result of sweating seriously degrades its thermal insulation, a knowledge of the propagation of water is essential to the design of good clothing. In order to predict the water vapour transport properties of the clothing system as a whole, a knowledge of the water vapour resistance of each constituent material is required. This paper describes an apparatus designed to measure the water vapour resistance of all types of materials, including insulating fabrics such as piles and battings, that are used in arctic clothing systems.

The propagation of water vapour through a dry fabric is governed by an equation of the form:

$$(1) \quad M = A\Delta P/R$$

where  $M$  is the mass transmitted per unit time

$A$  is the area of the fabric

$\Delta P$  is the difference in partial pressure of water vapour across the fabric

and  $R$  is the vapour resistance of a unit area of the fabric.

Standard methods for the determination of  $R$  consist basically of placing the sample over a dish of pure water, at a fixed distance from the water surface, in a controlled temperature and humidity environment, and measuring the weight loss of the dish (1)(2). Such a test measures not only the resistance to the passage of water vapour of the sample but also that of the air gap between the water and the sample and that from the upper surface of the sample to the surrounding atmosphere. These extraneous resistances can be eliminated or estimated by a variety of techniques. For example, the effect of the air gap can be estimated by varying its thickness and noting the change in overall resistance (3) or the resistance between the sample and the atmosphere can be minimized by generating an air flow over the sample (1). However, neither of these methods is applicable to materials such as battings where the surface is not sufficiently well defined to permit accurate adjustment of an air gap and where the high air permeability of the material precludes generating an air flow.

These difficulties have been overcome by the apparatus described in this paper. In this apparatus, the sample is sandwiched between two layers of a microporous Teflon sheet which is highly permeable to water vapour (4). Thus, on one side, the liquid water can be brought into contact with the Teflon, eliminating the air gap and, on the other, dry air can be blown over the Teflon, minimizing the sample-to-atmosphere resistance. The resistance of the two layers of Teflon is taken into account by measuring the overall resistance of the apparatus with and without the sample in place.

### EQUIPMENT AND PROCEDURES

#### Description of the Apparatus

The apparatus is shown schematically in Figure 1 with the details of the sample holder in Figure 2. The upper portion of the sample holder contains distilled water separated from the sample by a sheet of microporous Teflon (4) supported by a stainless-steel mesh. The sample is sealed into a ring of silicone rubber (5) to prevent escape of water vapour at the edges. The sample is separated from the lower portion of the chamber by a second sheet of Teflon. Dry air is circulated, at a constant rate of about 4.8 l/min, through this chamber and drying tubes of  $\text{CaSO}_4$ . The sample chamber sits on a scale, readable to 0.1 g and its mass is noted every 5 or 10 minutes to obtain the mass loss rate. The vapour pressure above the sample is taken as the saturation vapour pressure of water at the temperature of the water bath, measured with a copper-constantan thermocouple to an accuracy of  $0.2^\circ\text{C}$ . The vapour pressure of the returning dry air is assumed to be that given by the manufacturer of the drying tubes (6) (dew point  $\sim -80^\circ\text{C}$ ) which is negligible.

The resistance for the passage of water vapour from the bath to the drying tubes is then given by equation 1 with  $\Delta P$  equal to the saturation vapour pressure at the water bath temperature. The mass loss rate is measured over a period of several hours, after an initial stabilization period of sufficient duration to establish a constant loss rate (about one-half hour for a non-hygroscopic material).

The resistance of the sample is taken as the difference in overall resistance with and without the sample in place, times a small correction factor;

$$(2) \quad R_{\text{sample}} = (R_{\text{with sample}} - R_{\text{without sample}}) \times C$$

The correction factor  $C$  arises because the area of the sample is about 15% larger than the area of the water surface. Hence the flow of water vapour is not strictly perpendicular to the water surface and the rate is slightly larger than that expected from equation 1.  $C$  has been calculated from a numerical solution of Laplace's equation, which governs the vapour flow, in the actual experimental geometry (7). The results are shown in Figure 3, as a function of sample thickness, for a constant sample area equal to 1.15 times the water surface area.

#### Sample Preparation

The samples are sealed into a ring of silicone rubber by means of a rotational mold shown in cross section in Figure 4. The sample is held between two aluminum plates separated by the nominal thickness of the sample. The mold is spun at 1800 rpm and a mixture of room temperature vulcanizing rubber and hardener (5) is fed onto the top plate. The rubber flows to the outside rim of the mold forming a ring which seals the edges of the sample. The height of the ring is the thickness of the sample plus 12 mm above and below. The sample holder has a 12-mm shoulder on the side of each of the upper and lower chambers (see Figure 2) so that when the sample is placed in the holder the two layers of Teflon are held at a spacing equal to the nominal thickness of the sample. In this way the compression of the sample is maintained at a known value during the measurement.

#### RESULTS AND DISCUSSION

The performance of the apparatus was tested by measuring the vapour diffusion resistance of air gaps of thickness in the range 1 to 8 mm. The results are shown in Figure 5 where the overall resistance of the apparatus is plotted versus the gap thickness. To correct for the area discrepancy mentioned above the thickness has been divided by the correction factor  $C$ . The resistance is expressed as the thickness of a layer of still air expected to have that resistance. This latter quantity is calculated from handbook (8) values of the diffusion constant for water vapour into air.

The graph is expected to be a straight line of unit slope, the zero thickness intercept giving the residual resistance of the apparatus without a sample. The line drawn in Figure 5 is the best-fit straight line of unit slope and agrees with the data within the random experimental error.

The error arises primarily from the inaccuracy in the weight measurements which are sensitive to fluctuations in room temperature and to air currents. The measurements improve with the length of time over which they are taken. These data are an average of three trials at each point taken over about 3 h per trial. The error bars indicate statistical standard error among the three trials.

The resistance values measured for a few fabrics of current interest to the clothing research program are listed in Table I.

#### CONCLUSION

It is concluded from the results shown in Figure 5 that the apparatus is accurate to a resistance of about 0.5 mm equivalent air gap without systematic error.

TABLE I

## Water-Vapour Resistance of Some Textile Materials

Sample	Thickness (mm)	R ( $\text{m}^2 \text{ s pa kg}^{-1}$ )	R (mm equivalent still air)
Thinsulate <sup>a</sup> M 400	7.7	$(6.3 \pm .3) \times 10^7$	$11.5 \pm .5$
Thinsulate <sup>b</sup> M 530	6.4	$(4.0 \pm .6) \times 10^7$	$7.3 \pm 1.0$
Thinsulate <sup>c</sup> CS 150	3.2	$(2.6 \pm .2) \times 10^7$	$4.8 \pm .4$
Goretex <sup>d</sup>	0.36	$(1.83 \pm .04) \times 10^7$	$4.10 \pm .07$
Text 7-6-5 <sup>e</sup>	0.38	$(0.42 \pm .02) \times 10^7$	$0.76 \pm .04$

\* Laminated between Nylon-Tricot and Nylon-Poplin

- a. 3M Company, microfibre non-woven polypropylene batting, 400 g/m<sup>2</sup>.
- b. As above, 530 g/m<sup>2</sup>.
- c. 3M Company, microfibre non-woven polyester/polypropylene composite batting, 150 g/m<sup>2</sup>.
- d. Gore Industries Ltd, microporous/Teflon Sheet.
- e. 50/50 Nylon/cotton twist fabric, 170 g/m<sup>2</sup>, 0G107 dye.

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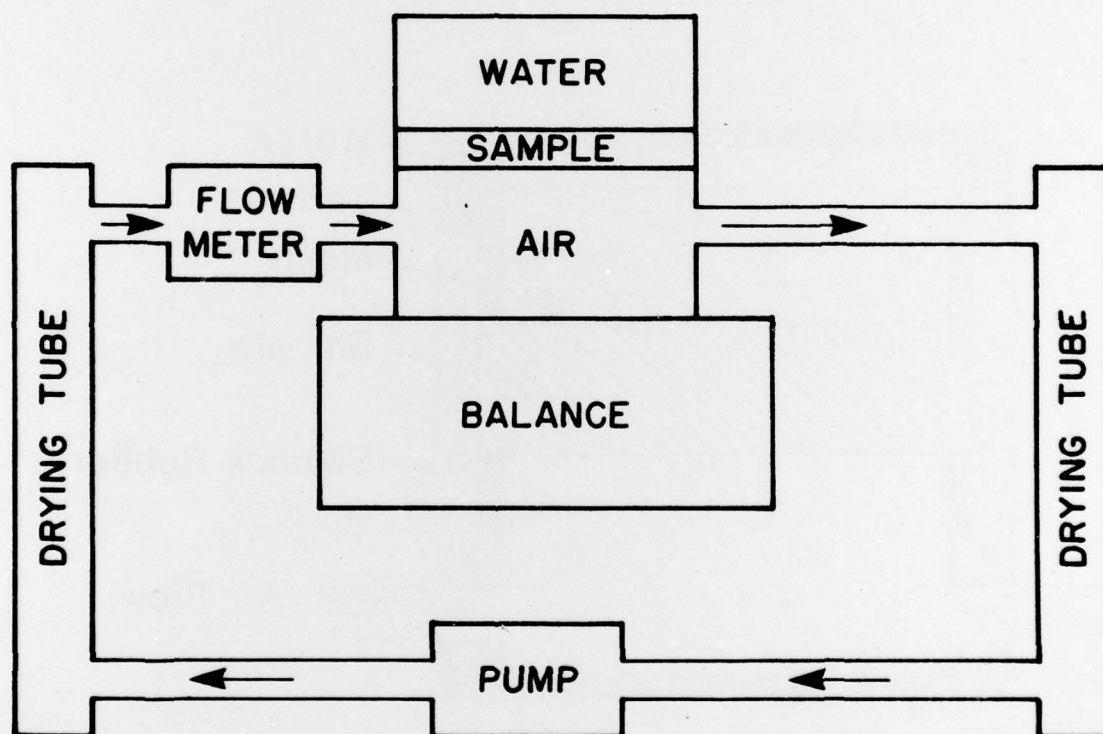


Figure 1. Schematic diagram of the apparatus. The sample is held between two layers of microporous Teflon with water on one side and dry air on the other. The mass of the sample holder is monitored to give the water vapour diffusion rate.

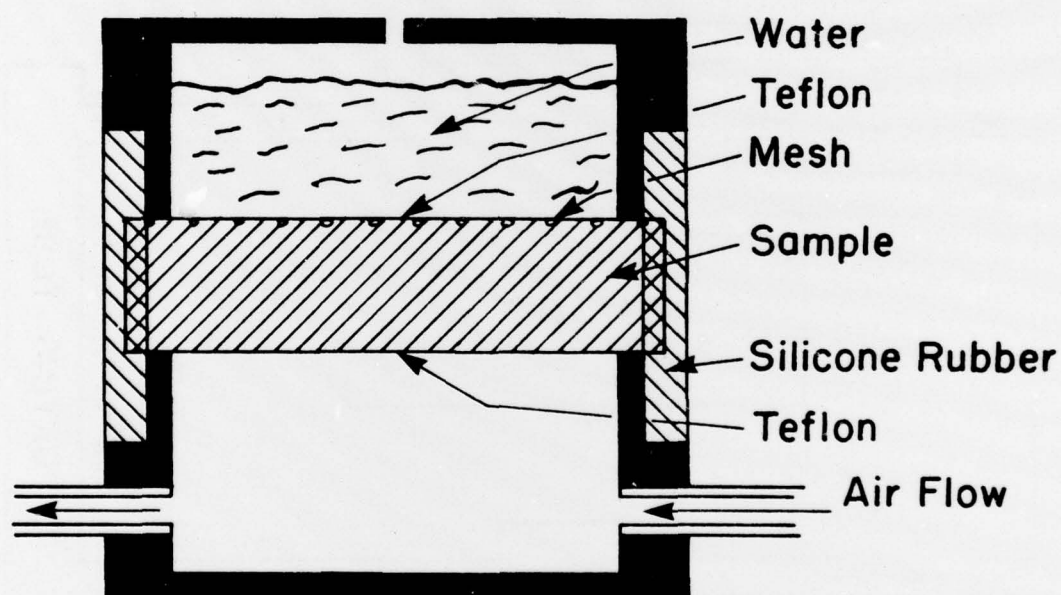


Figure 2. Details of the sample holder. The sample is embedded in a ring of silicone rubber to prevent leakage of water vapour at the edges. The upper layer of Teflon is supported by a stainless-steel mesh.

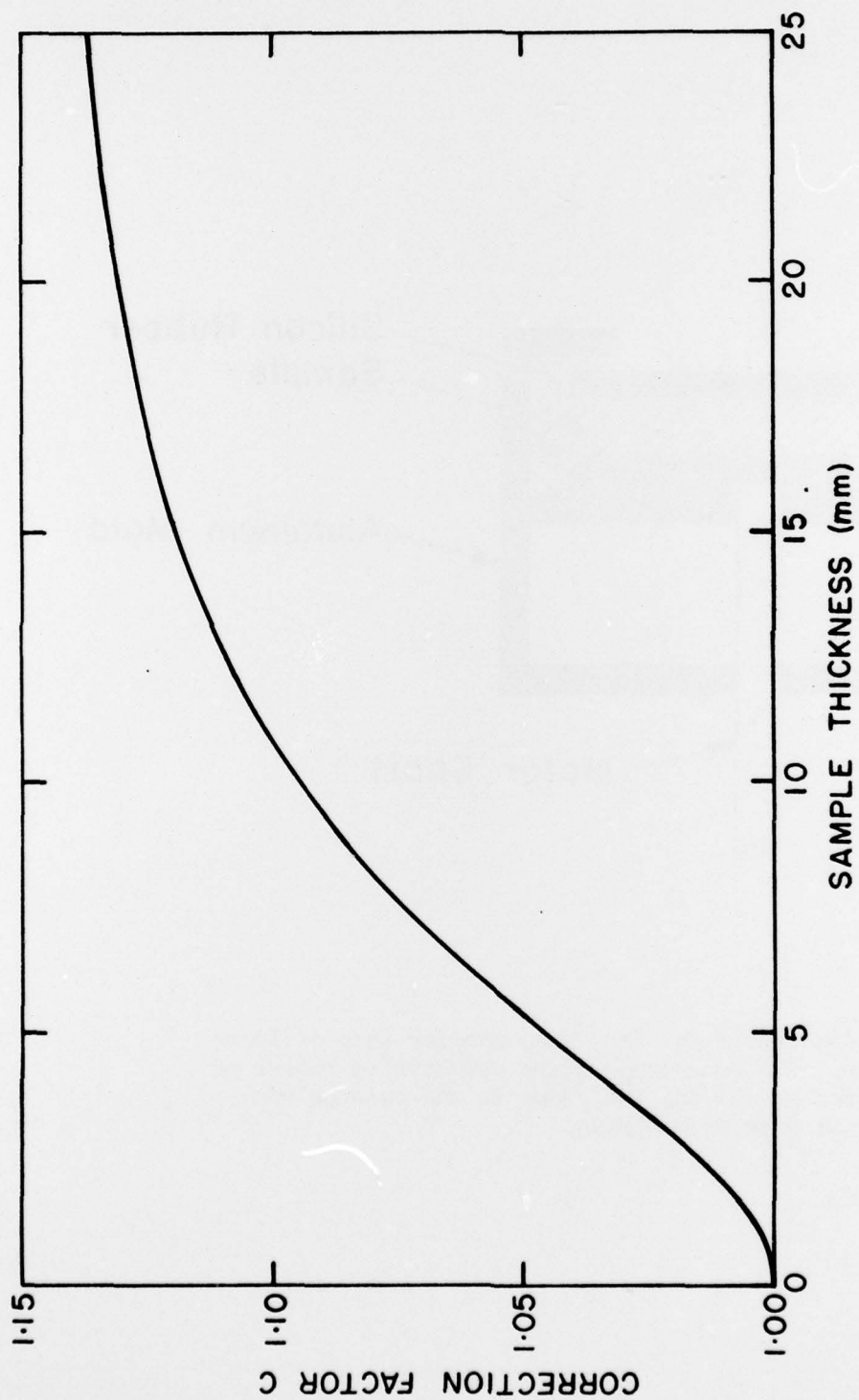


Figure 3. Correction factor to compensate for the difference in area between the sample and the water surface. The calculation is for a fixed sample area and varied thickness.

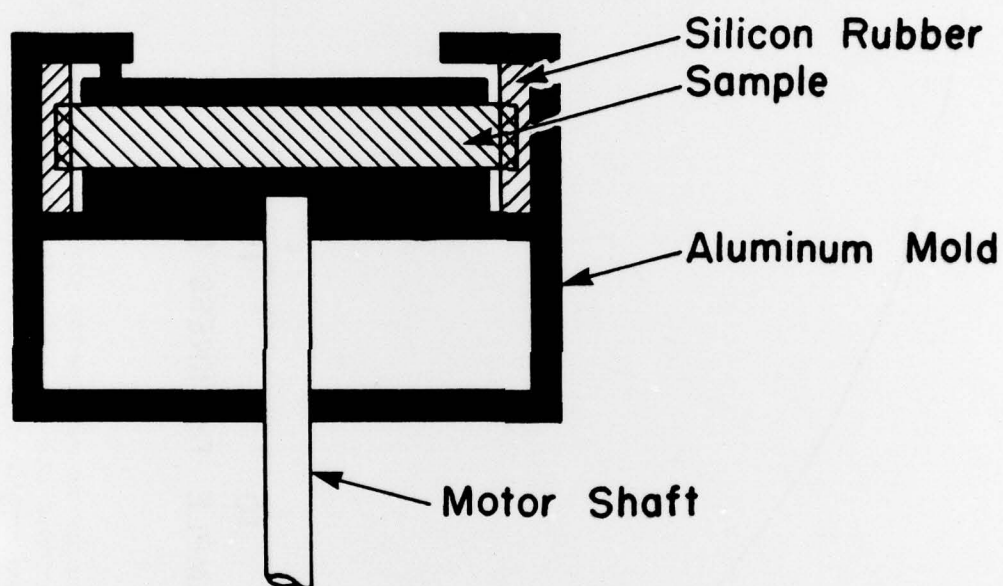


Figure 4. Rotational mold for imbedding samples into silicone rubber. The room-temperature vulcanizing rubber is injected at the top and flows to the outside rim where it sets into a ring.

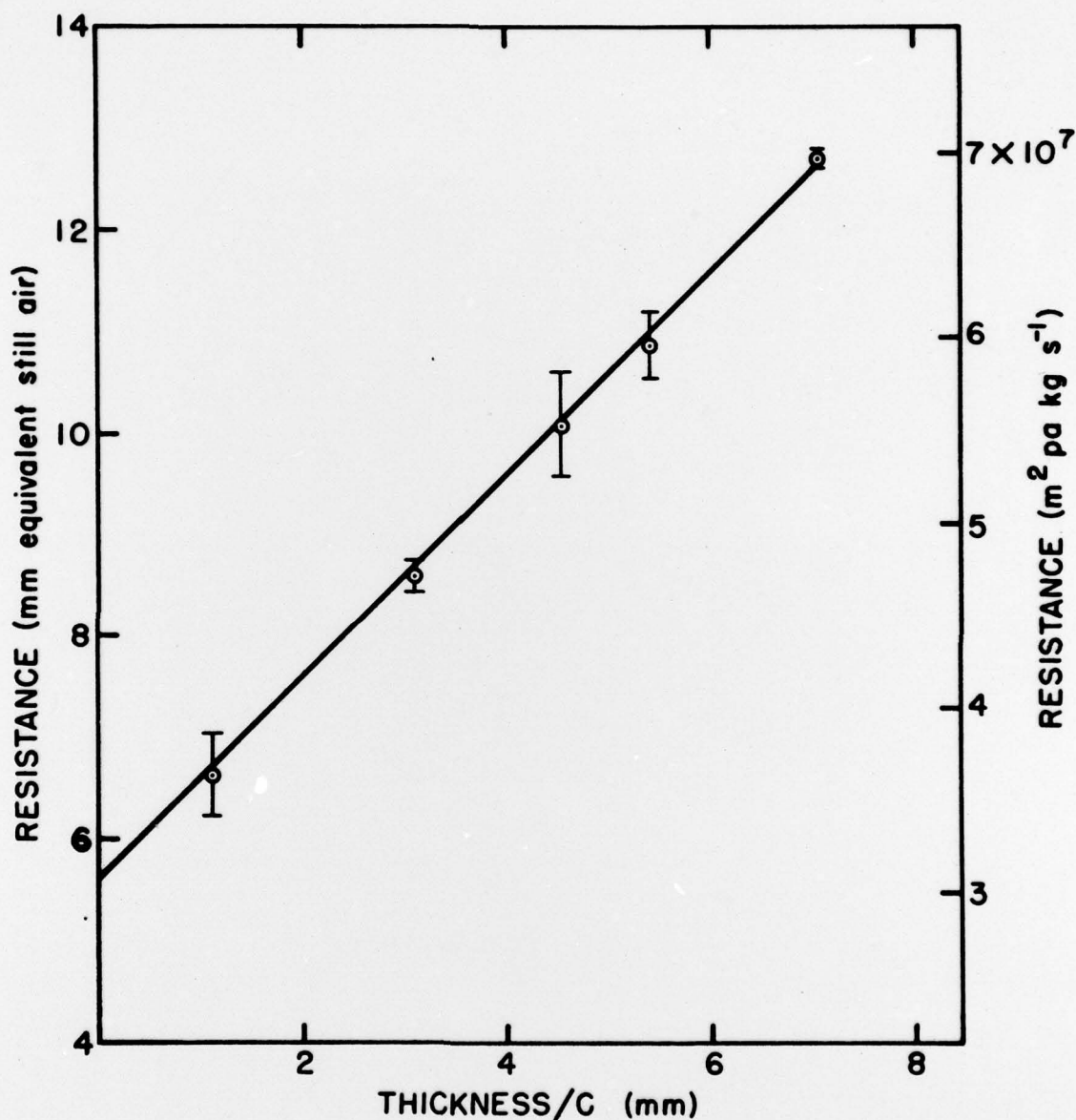


Figure 5. Overall resistance of the apparatus with the sample replaced by air layers of various thickness. The thicknesses have been divided by the correction factor  $C$  to account for the area discrepancies. The resistance is expressed as the thickness of a perfectly still air layer having that resistance. The line is of unit slope with intercept adjusted to fit the data points.

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